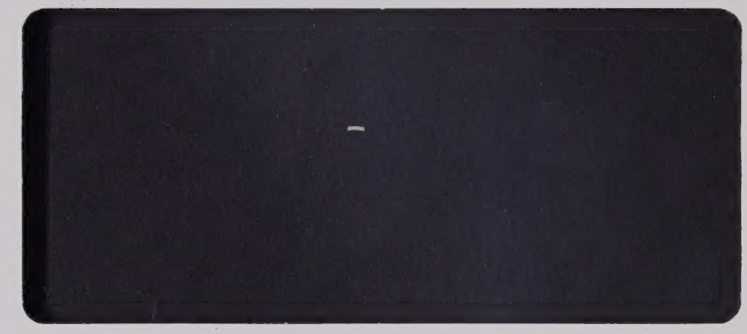
OPERATING AND SERVICE DATA
FOR
GMC MODELS 460 AND 460B
THERMOELECTRIC POWER METER
FOR SERIAL NOS. --2835 & HIGHER

GENERAL MICROWAVE

460/460B

GENERAL MICROWAVE CORPORATION



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GENERAL MICROWAVE CORPORATION
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FARMINGDALE, NEW YORK 11735

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NOTE

The Model 460B is similar to the Model 460, as described in this handbook. The major differences consist of several component changes and the addition of a network to compensate for the non-linearity of the GMC Model N423 tft Power Head when used to measure power levels in excess of one watt. Unless otherwise indicated, all data contained herein apply equally to both models.

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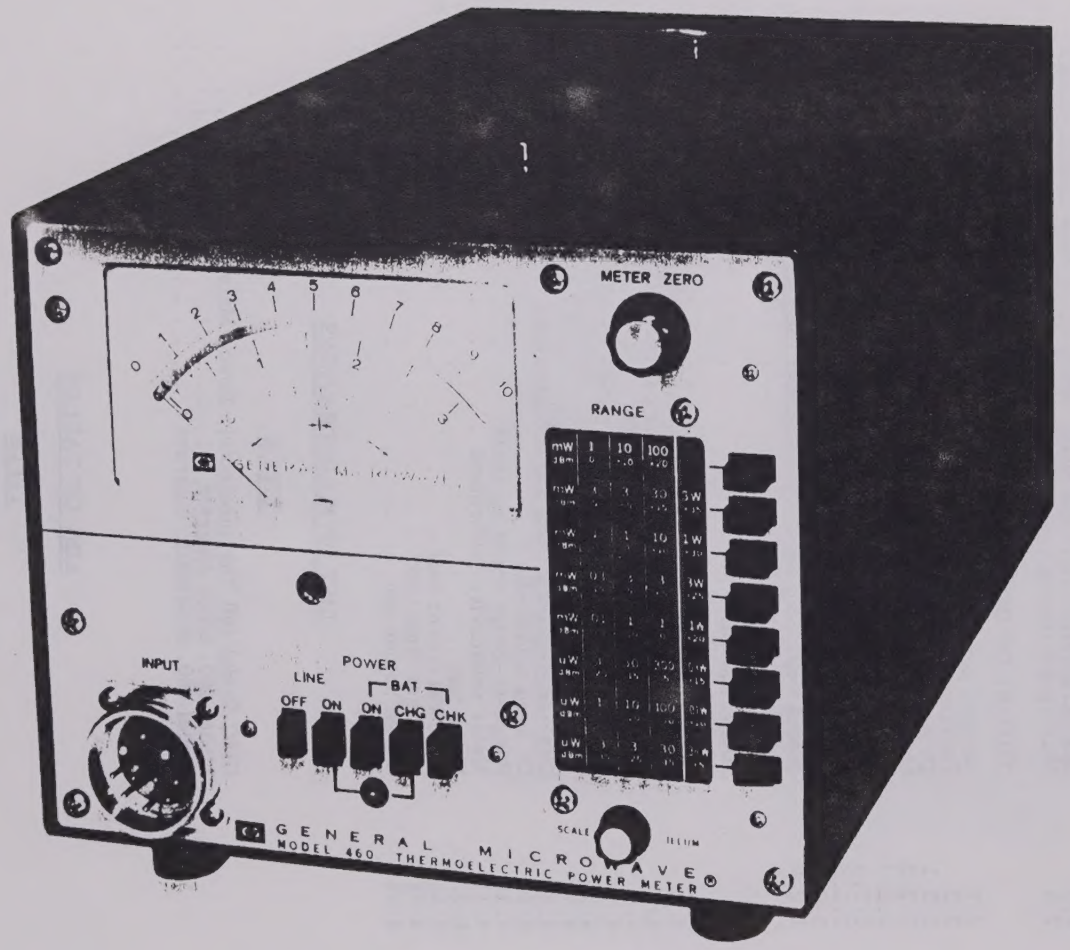


Figure 1.1 GMC Model 460 Thermoelectric Power Meter

SECTION I - GENERAL

1.1 DESCRIPTION

1.2 The GMC Model 460 Thermoelectric Power Meter (figure 1.1), in conjunction with the GMC 420 Series of tft® * Power Heads, is a highly accurate instrument which measures radio frequency power over an extremely wide frequency and power range. It measures and indicates the average power absorbed by the tft power head in use, and accepts amplitude and frequency modulated, pulsed and CW signals. The Model 460 can also be used with the GMC 430 Series of Miniature tft Power Heads when the superior average power range, thermal stability and low noise characteristics of the 420 Series are not required. Table 1.1 lists tft power head characteristics.

1.3 The Model 460 features automatic scale selection, which ensures that only the scale corresponding to the sensitivity of the tft power head in use is activated. Other features include a switch which enables the selection of either "NORMAL" or "FAST" amplifier response time, an output jack for measurement systems using external recorders or digital voltmeters, and two paralleled input connectors which permit tft power head connections at the front or rear of the Model 460.

1.4 The Model 460 is suitable for use in a wide variety of applications, including portable and field use (when used with the optional Model 981 Rechargeable Battery Pack), fixed stations and laboratory bench setups. Since all tft power heads will operate with the Model 460, a single instrument with different tft power heads can be applied to a wide variety of measurement applications. The Model 963R Junction Box, which permits simultaneous connection of up to five tft power heads, facilitates many applications. Models 963R can be cascaded to permit operation of an even greater number of tft power heads.

1.5 By using the proper rack adapter or conversion kit, the Model 460 can be rapidly rack-mounted by itself, with any other GMC unit packaged in the half-rack configuration, or with 7-25/32" wide half-rack units of other manufacturers.

1.6 Refer to tables 1.2 and 1.3 for additional data.

TABLE 1.1 - CHARACTERISTICS OF tft POWER HEADS

MODEL NO.	FREQUENCY RANGE (GHz)	WAVEGUIDE TYPE	CONNECTOR TYPE	AVERAGE POWER RANGE		MAX. PEAK POWER (WATTS)	MAX. VSWR
				FROM	TO		
N420	0.01-12.4	Coaxial	N Male	-35 dBm 0.3 uW	+10 dBm 10 mW	3	1.5**
N421				-25 dBm 3.0 uW	+20 dBm 100 mW	30	
N422				-45 dBm 0.03 uW	0 dBm 1 mW	0.3	
N423				-5 dBm 0.3 mW	+35 dBm 3 W	100	1.5+
N430				-15 dBm 30 uW	+10 dBm 10 mW	3	1.5**
N431				-5 dBm 0.3 mW	+20 dBm 100 mW	30	
N432				-25 dBm 3.0 uW	0 dBm 1 mW	0.3	
440	0.01-18.0	Coaxial	SMA Male	-35 dBm 0.3 uW	+10 dBm 10 mW	1	1.35++
X420	8.2-12.4	RG-52/U	UG-39/U	-35 dBm 0.3 uW	+10 dBm 10 mW	3	1.5
U420	12.4-18.0	RG-91/U	UG-419/U			3	
K420	18.0-26.5	RG-53/U	UG-595/U			0.5	
A420	26.5-40.0	RG-96/U	UG-599/U			0.5	1.65

* Thin-film thermoelectric.
** Except in the range from 10 to 15 MHz where VSWR may rise to 1.75.
\+ Except in the range from 10 to 15 MHz where VSWR may rise to 1.75 and in the range from 11.5 to 12.4 GHz where VSWR may rise to 2.0.
++ Except in the range from 10 to 20 MHz where VSWR may rise to 1.65 and in the range from 8 GHz to 18 GHz where VSWR specification is 1.5.

TABLE 1.2 - SPECIFICATIONS

FEATURE	DESCRIPTIVE DATA
Power Ranges	Fifteen different ranges in four overlapping scales, with full scale readings of:
Frequency Range	10 MHz to 40 GHz, depending on the tft power head in use.
Accuracy	±1% of full-scale indication.
Temperature Range	0°C to +55°C
Response Time	Less than 1 second with the selector switch in the NORMAL position; approximately 100 ms in the FAST position.
Noise and Drift	Less than ±0.5% peak-to-peak of full scale on the lowest ranges (except for the high sensitivity position where it may rise to ±1% peak-to-peak) at constant ambient at "NORMAL" response time; decreases on higher ranges; increases at "FAST" response time.
Temperature Coefficient	Less than 0.1% per degree C.
Zero Carryover	Single electrical zeroing control carries over from range to range.
DVM/Recorder Output	Calibrated analog output [-1V dc full scale (±1/2% of full scale) for DVM use] or adjustable dc output (0 to -1V full scale) for recorder use. Minimum load resistance of 1000 ohms required.
Input Connectors	Two provided, one on front panel and one at the rear.
Meter	4-1/2", mirror scale, taut-band suspension.
Input Power	115/230 V ±10%, 50-1000 Hz, 5 watts.
Dimensions	6.8" H x 7.8" W x 12.6" D.
Weight	9 lbs.

μW	dBm	mW	dBm	W	dBm
0.3	-35	1	0	1	+30
1	-30	3	+ 5	3	+35
3	-25	10	+10		
10	-20	30	+15		
30	-15	100	+20		
100	-10	300	+25		
300	- 5				

TABLE 1.3 - OPTIONAL ACCESSORIES

MODEL	DESCRIPTION
305A	Calibrator - Provides all required calibration voltages for the Model 460.
963R	Junction Box - Each permits operation of up to five tft power heads with one Model 460. They can be cascaded.
W985	Voltmeter Adapter Cable - Converts the Model 460 to a dc microvoltmeter; 3 microvolts full scale to 10 millivolts full scale.
981	Rechargeable Battery Pack - Permits portable or field use of the Model 460.
983	Rack Adapter (19") - Permits rack-mounting of the Model 460 by itself, with any other GMC unit packaged in the half-rack configuration, or with 7-25/32" wide half-rack units of other manufacturers.
984	Conversion Kit - Permits rack-mounting of the Model 460 into suitable rack adapters of other manufacturers.

SECTION II - OPERATION

2.1 OPERATING CONTROLS, INDICATORS AND CONNECTORS

The Model 460 operating controls, indicators and connectors are located on both the front and rear panels. Those on the front panel are:

RANGE: An eight-position push-button switch which permits selection of the desired operating power range. Fifteen different ranges in four overlapping scales are available, and the scale corresponding to the sensitivity of the tft power head in use is automatically activated. The overlay markings are given in both watts and dBm, and are full-scale values. Only those markings corresponding to the scale in use and the manually-selected range are illuminated.

METER ZERO: This potentiometer is used to electrically zero the instrument. Once set, it need not be adjusted when changing ranges.

SCALE ILLUM: This potentiometer is used to adjust the intensity of the 31 range indicating lamps.

INPUT: This ten-pin connector provides all interconnections with the tft power head in use. An identical connector, wired in parallel, is located at the rear of the Model 460. Either may be used.

POWER: A five-position push-button switch which energizes the Model 460 using either ac line power (LINE ON button) or optional battery power (BAT ON button). It also permits the condition of the batteries to be checked (BAT CHK button) and permits the batteries to be charged (BAT CHG button). When in the LINE ON position, a trickle charge is applied to the batteries, and when in the BAT CHG position, the ac line power is completely diverted for battery charging purposes. The associated indicator lamp will glow only when one of these two buttons is depressed.

The controls and connectors located at the rear of the Model 460 are:

115V-230V LINE: This switch permits the application of either 115 volt or 230 volt ac power. Ensure that the switch position is properly set prior to the application of power to avoid equipment damage. If replacement of the associated fuse becomes necessary, ensure that the replacement conforms with the description given in the Table of Replaceable Parts.

OUTPUT: These binding posts provide either a calibrated analog output of the measured rf power (-1 volt dc full scale) for digital voltmeter use, or an adjustable dc output (0 to -1 volt full scale) for recorder use.

OUTPUT ADJUST: This potentiometer/switch controls the voltage available at the OUTPUT connector. When set to its detented position (fully clockwise) and with a full-scale indication on the 10 meter scale, a -1 volt dc calibrated analog voltage is provided at the OUTPUT connector. (A -0.3 volt dc calibrated analog voltage will be provided with a full-scale indication on the 3 meter scale.) When the control is not in the detented position, an adjustable linear 0 to -1 volt dc voltage proportional to the measured rf power is provided at the OUTPUT connector.

RESPONSE: This switch controls the amplifier response time (and noise level). When in the NORM position, the response time of the amplifier will be less than one second, and in the FAST position, about 100 ms. (Note, however, that the noise will also increase when in the FAST position, particularly in the lower ranges.)

INPUT: This connector is wired in parallel with the INPUT connector on the front panel. Either may be used for interconnection with the tft power head in use.

2.2 INSTALLATION AND OPERATING PROCEDURES

With the exception of those in step 2.2.1 below, there are no special precautions to be observed when installing or using a Model 460 and tft power heads other than the normal good practices associated with accurate measurement procedures, and the use and handling of microwave components. In these respects, it is suggested that a warm-up period of about five minutes be allowed before use to permit circuit stabilization. The flange or connector of the tft power head should be handled with care to avoid scratching or marring the surfaces and connecting parts, and should be covered with a protective cap when not in use to prevent accumulations that can affect performance. Finally, the power ratings of the tft power heads should never be exceeded since permanent damage to the tft element may result. Although the power ratings are conservatively applied, the margin of safety should not be deliberately narrowed.

If it is desired to use a recorder to obtain a plot of power output versus time, or to connect a digital voltmeter to the amplifier output for increased accuracy, use the OUTPUT connector. Refer to the discussion of the OUTPUT connector and OUTPUT ADJUST control above for additional details.

If it is desired to rack-mount the Model 460, use a GMC Model 983 Rack Adapter, which can be used to mount any one or two GMC half-rack configuration units. (To rack-mount the Model 460 by itself, order a GMC P/N 5315-3 blank panel with the Model 983.) Some half-rack units of other manufacturers can be mounted into a Model 983 with a Model 460, and the Model 460 can be mounted into some rack adapters of other manufacturers. It is suggested that the GMC factory be contacted regarding the use of other manufacturers' equipment in conjunction with GMC equipment.

To operate a Model 460, proceed as follows:

2.2.1 If ac line power is to be used, set the 115V-230V LINE switch as required, make the connection to the power source, and depress the POWER LINE ON button. The associated

indicator lamp should glow. Note that beat notes will arise between certain line frequencies and harmonics of the chopper frequency, producing erratic performance of the Model 460. The forbidden line frequency bands are 53-57, 75-90, 160-172, 243-255, 326-338, 409-421, 492-504, 575-587, 658-670, 741-753, and 824-836 Hz.

If battery power is to be used, check the battery condition using the POWER BAT CHK button, and depress the POWER BAT ON button. The Model 460 can be operated about 16 hours on a fully-charged pair of batteries, and the charging cycle is about 16 hours for a complete charge. Refer to the Model 981 literature for complete battery data.

2.2.2 Connect the tft power head to either INPUT connector.

2.2.3 Depress the lowest RANGE button.

2.2.4 Determine the effective efficiency from the graph mounted on the tft power head and set the EFF control on the tft power head to the value obtained.

2.2.5 Zero the Model 460 meter using the METER ZERO control.

2.2.6 Depress the desired RANGE button, connect the tft power head to the source of rf power to be measured, and read the power on the meter. (If the power to be measured is not approximately known, use the least sensitive tft power head available, depress the upper RANGE button and, after application of rf power, reduce the power range and/or change tft power heads as required.)

2.2.7 To turn-off the Model 460, depress the POWER LINE OFF button. This step applies equally to instruments using battery power or ac line power.

2.3 SPECIAL APPLICATION OF THE MODEL 460 TO DC VOLTAGE MEASUREMENTS

The Model 460 is a high quality, sensitive dc microvoltmeter which can be employed for null detection or dc voltage measurement purposes. The nominal full-scale sensitivity of the instrument is 1.36 microvolts on the lowest range. Each adjacent RANGE button corresponds to a 10 dB change to the full-scale voltage rating (not the 5 dB shown on the lamp overlay, which is a result of the square-law characteristic of the tft power heads) and thus, the 1-3-10 progression of the power scales is preserved when measuring voltage. By employing the Model W985 Voltmeter Adapter Cable, the Model 460 will indicate directly in voltage starting at 3 microvolts full-scale on the lowest range and extending to 10 millivolts on the highest range. Refer to the Model W985 literature for additional details.

Because of the low levels involved, extreme care must be exercised when measuring voltage to avoid generating spurious emf's. Avoid soldered connections, except when made with low-thermal emf solder, and junctions of dissimilar metals. Crimped copper connections with large thermal masses are best.

Since the Model 460 meter is not center-zeroed and does not employ a floating input, only dc voltages of positive polarity can be measured. It is possible to electrically zero the meter at mid-scale on the lower ranges. This is particularly useful for null measurement work.

2.4 MULTI-POINT TESTING WITH THE MODEL 460

Since the tft power heads are rf power-to-dc voltage transducers, it is possible to successively connect a number of different tft power heads to a Model 460, thereby enabling measurement of power at different points in an rf network, without readjustment of the Model 460. There is no danger of upsetting the network characteristics under these conditions, since the tft power heads retain their matched characteristics, even when not connected to the Model 460.

To facilitate the use of a number of tft power heads, a five-input junction box, Model 963R, is available. Switching is performed by a front-panel mounted low-noise rotary switch. By cascading junction box units, a larger number of tft power heads can be used in conjunction with one Model 460.

SECTION III - THEORY OF OPERATION

3.1 GENERAL CIRCUIT DESCRIPTION

The Model 460 is basically a dc amplifier with the attributes of very low noise, high gain and high gain stability, with a self-contained meter to indicate its output signal. Because of the extremely low dc signals involved (less than 1.5 microvolts full-scale on the most sensitive range), a chopper-carrier system is employed to avoid drift.

Figures 3.1 and 3.2 are block and schematic diagrams, respectively, of the overall unit. The dc input signal from the tft power head is applied to the modulator. The square-wave output signal of the modulator is stepped-up by the input transformer and applied to the low-noise preamplifier. The square-wave signal is amplified in this circuit and coupled to the filter amplifier, where much of the noise and other spurious signals are filtered out. The resulting sine-wave signal is then amplified and coupled to the phase splitter. This circuit provides the phase splitting action required to provide the demodulator input. The full-wave demodulator, which is synchronously driven with the modulator, recovers the input dc signal at a greatly amplified level.

The output of the demodulator is applied to the integrating amplifier. This circuit provides additional signal gain, and also reduces the amplifier bandwidth to the degree required consistent with the selected response time (and noise level). The output of the integrating amplifier is coupled back to the modulator and input transformer circuit through a RANGE switch network. This feedback path provides a high degree of degeneration and, thus, gain stability, and at the same time provides a means of accurate control of the overall amplifier gain.

The output of the integrating amplifier is also applied to the compensation network in the tft power head, where compensation is made for the sensitivity of the tft power head, and for its inefficiency at the frequency of the signal under measurement. The return from the tft power head compensation network is applied to the inverting amplifier, and the output of this circuit drives the front-panel meter through a second RANGE switch network. The output of the inverting amplifier is also made available at the recorder/digital voltmeter OUTPUT jack J4.

Two identical 8-volt regulated power supplies are included in the Model 460. One provides a positive output, and the other a negative. In addition, provisions are contained for mounting an optional rechargeable battery pack to power the unit.

Automatic scale selection is provided in the Model 460. The operation of this network is controlled by the various interlock combinations associated with pins 4, 5 and 6 of the tft power head connector.

The modulator/demodulator drive circuit is a conventional free-running multivibrator which provides the required 83 Hz signal.

3.2 DETAILED CIRCUIT DESCRIPTION

3.2.1 DC AMPLIFIER.

3.2.1.1 MODULATOR AND INPUT TRANSFORMER. The input signal to the Model 460 is applied to the moving arm of modulator G1-A, which is one half of a mechanical chopper. The dc amplifier feedback signal and the dc offset voltage from the METER ZERO control R23 are applied to the center-tap of the primary of input transformer T1. Therefore, the difference between the input and feedback/dc offset signals is alternately applied to each half of the transformer primary, producing a full-wave signal (square-wave). The signal is stepped up in the transformer and applied to the low-noise preamplifier.

To eliminate thermal emf's in the input circuit, copper leads are employed throughout, and all connections are soldered with low-thermal emf solder. The modulator and input transformer also employ copper leads, and the transformer is carefully shielded to minimize hum pickup. The input connector employs special pins for the signal lines.

3.2.1.2 LOW-NOISE PREAMPLIFIER. The square-wave signal from the modulator and input transformer is amplified in the Q1 and AR2 stages, and coupled to the filter amplifier. The gain of the AR2 stage is controlled by resistor R12, R14, R16 or R18, and is determined by the RANGE switch setting.

3.2.1.3 FILTER AMPLIFIER. The square-wave signal from the low-noise preamplifier is amplified in the AR3 stage, which is an active bandpass amplifier/filter network centered at 83 Hz. Fine tuning for the stage is provided by means of potentiometer R39. The resulting 83 Hz filtered sine-wave signal is then coupled to the phase splitter and demodulator.

3.2.1.4 PHASE SPLITTER AND DEMODULATOR. The signal from the filter amplifier is applied to the Q2 stage, which, together with the Q3 stage, drives the demodulator. The full-wave demodulator is synchronously driven with the modulator at an 83 Hz rate. Therefore, much of the non-synchronous noise and spurious signals present in the carrier are eliminated.

3.2.1.5 INTEGRATING AMPLIFIER. The output of the demodulator is applied to the AR4 stage which, together with Q4 and feedback resistor R57, and by virture of the feedback capacitor (C32 or C33), forms an integrating amplifier. The integrating amplifier stage feedback capacitor determines

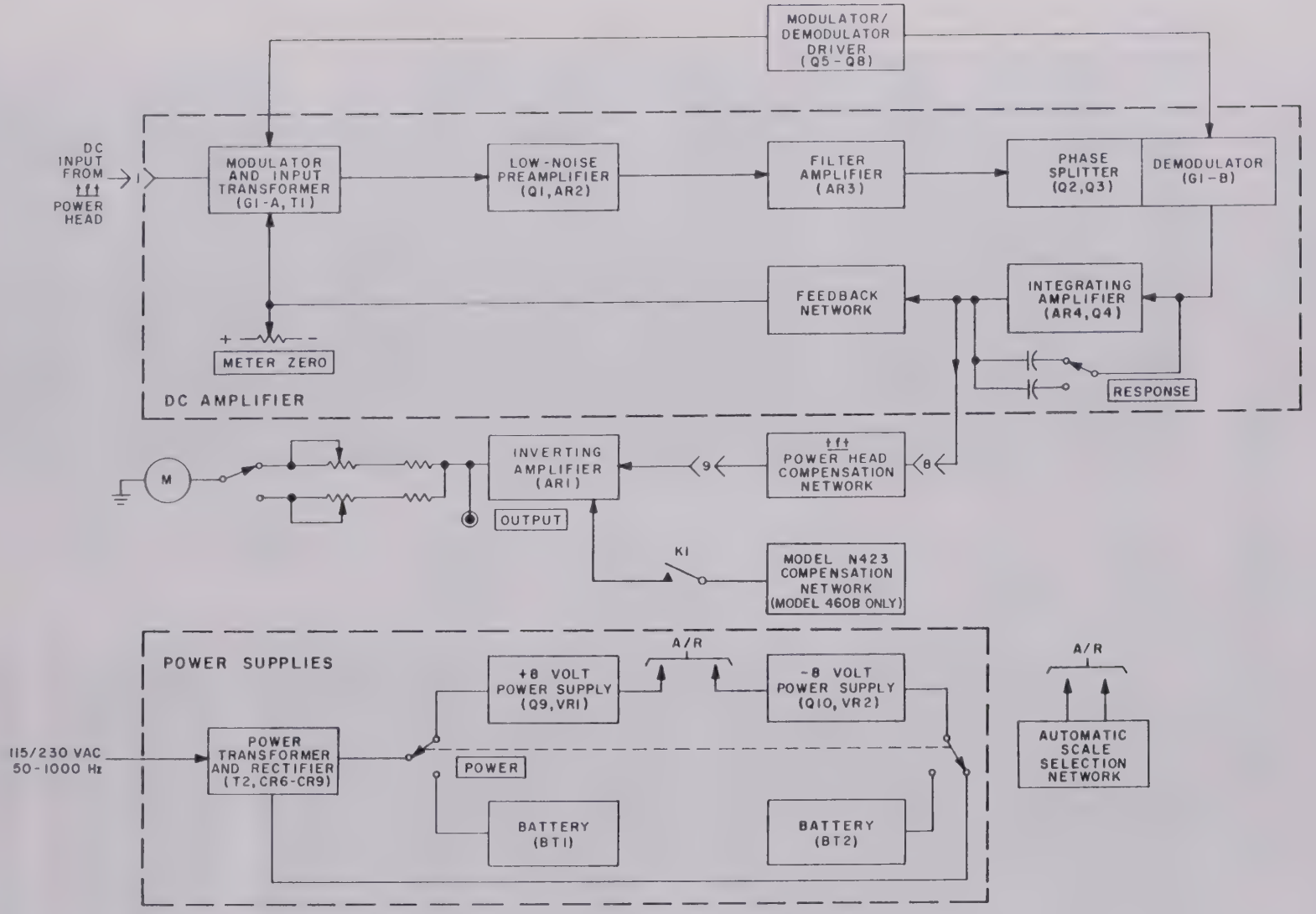
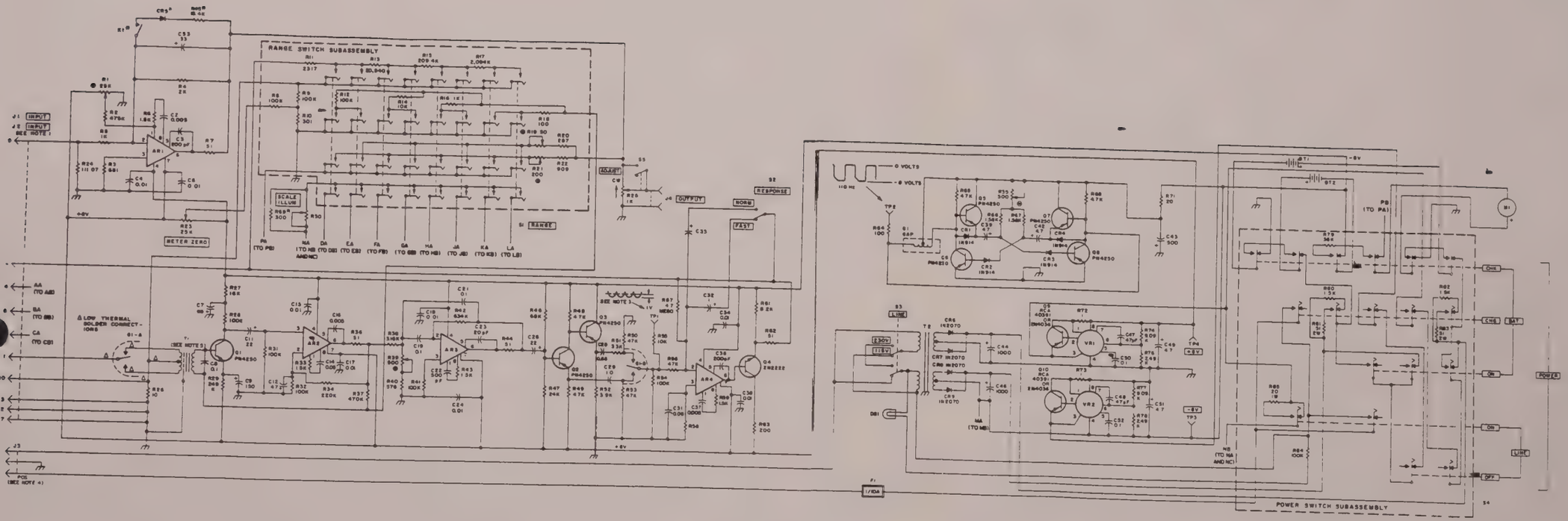
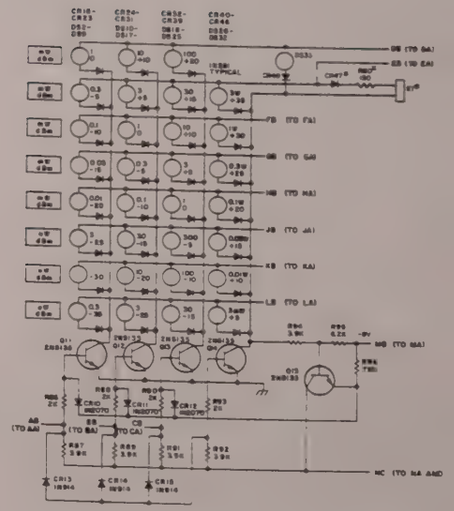


Figure 3.1 Model 460, Block Diagram





NOTES:
1. J1 AND J2 ARE FRONT AND REAR PANEL INPUT CONNECTORS RESPECTIVELY, AND ARE CONNECTED IN PARALLEL.
2. UNLESS OTHERWISE SPECIFIED
   RESISTANCES ARE GIVEN IN OHMS
   CAPACITANCES ARE GIVEN IN MICROFARADS
3. WAVEFORM OBSERVED WHEN S84 IS REMOVED AND TOP RANGE BUTTON IS DEPRESSED
4. INDICATES COMPONENTS USED ONLY IN THE MODEL 460B
5. WIRING OF CONNECTOR J3 IS SHOWN BELOW:
   FRONT VIEW
   POS-TIVE CONTACT (CONNECT TO F1)
6. DO NOT MAKE RESISTANCE CHECKS ON TRANSFORMER T1

Figure 3.2 Model 460, Schematic Diagram

the bandwidth of the dc amplifier, and is controlled by the setting of the RESPONSE switch S2. When in the NORM position, the response time of the Model 460 is less than 1 second and the noise is less than ±1% peak-to-peak of full scale on the most sensitive range. When the RESPONSE switch is set to FAST, the response time decreases to approximately 100 milliseconds, but the noise may increase above the ±1% specification, particularly in the lower ranges.

3.2.1.6 FEEDBACK NETWORK. The integrating amplifier dc output provides the feedback signal around the entire dc amplifier. The magnitude of the feedback signal, and therefore, the dc amplifier gain, is determined by the ratio of the sum of resistors R11, R13, R15 and R17 (changed by the RANGE switch setting), and the value of resistor R26.

The presence of spurious dc signals at the input to the dc amplifier must be anticipated because of thermal emf's, as well as any slight unbalance that may be present in the tft power head. Accordingly, to correct for these offset signals, a small adjustable dc voltage is introduced with the feedback signal. This voltage is derived from the positive and negative power supplies and is controlled by the setting of the METER ZERO potentiometer R23.

3.2.2 tft POWER HEAD COMPENSATION NETWORK.

The integrating amplifier dc output is also applied to the tft power head compensation network, where compensations for the sensitivity and efficiency variations of the tft power head are made. Since both the absolute sensitivityand efficiency of all tft power heads differ, the Model 460 gain must be varied with each tft power head employed. This is accomplished by the calibration potentiometer in the tft power head, which is adjusted as part of the calibration procedure for the tft power head, and by the efficiency potentiometer, also located in the tft power head, which is adjusted by the operator to compensate for the tft power head inefficiency at the particular frequency of the rf signal under measurement. This permits the Model 460 to be used, without adjustment, with any tft power head.

3.2.3 INVERTING AMPLIFIER.

The compensated return from the tft power head is amplified and inverted in the AR1 stage. Potentiometer R1 is a dc offset adjustment for the stage. The output of AR1, which is an analog voltage varying from 0 to -1 volt as a function of the measured rf power level, is applied to the front-panel meter M1 and the OUTPUT jack J4. Full-scale meter adjustments are provided by means of potentiometers R19 (for readings on the 3 scale) and R21 (for readings on the 10 scale). The signal level at the OUTPUT jack can be conveniently adjusted for recorder use by means of the ADJUST potentiometer R25, or alternately, can be maintained at a -1 volt full scale level for DVM use or calibration purposes by rotating the ADJUST potentiometer fully clockwise to its detented position. This closes switch S5, thereby shorting out potentiometer R25.

3.2.4 POWER SUPPLIES.

Two identical regulated 8 volt power supplies are included in the Model 460. One provides a positive output and the other a negative. The positive supply consists of Q9 and VR1, and associated components. The full-wave rectified output of CR6 and CR7, at about 18 volts, is applied to current booster stage Q9 when the POWER LINE ON button is depressed. The output of the Q9 stage is applied to the voltage regulator stage VR1, and the regulated 8 volt output of this stage is made available to the Model 460 as required. The negative power supply consists of Q10 and VR2, and associated components. The full wave rectified output of diodes CR8 and CR9 is similarly applied to this power supply through the POWER switch.

The 18 volt rectified outputs of CR6/CR7 and CR8/CR9 are made available through the POWER switch to the (optional) batteries. When the POWER LINE ON button is depressed, the batteries receive a trickle charge by means of resistors R80 and R82, and when the BAT CHG button is depressed, the batteries receive a full charge by means of resistors R81 and R83.

The condition of the batteries can easily be checked by means of the BAT CHK button, a separate front-panel meter scale, and the POWER switch, which places the batteries in series with each other, the meter, and limiting resistor R79.

3.2.5 AUTOMATIC SCALE SELECTION NETWORK.

This network consists of transistors Q11 through Q13 (corresponding to the Series 422, 420 and 421 tft Power Heads, respectively), transistor Q14 (corresponding to the Model N423 tft Power Head), emitter-follower Q15, and associated circuitry. Transistors Q11, Q12 and Q13 are normally biased "on", thereby establishing a potential at their collectors which is essentially at ground level. When a Series 422, 420 or 421 tft Power Head is connected to the Model 460, two of the three interlock pins (4, 5, and 6) are grounded, since the corresponding pins are grounded in the tft power head. These grounded pins bias the associated two transistors "off". Since the collectors of the three transistors are connected to the corresponding rows of indicator lamps (vertical), only that row of lamps which corresponds to the appropriate tft power head remains activated (by means of the ground potential). When a RANGE button is depressed, a positive potential is applied to the row of indicator lamps corresponding to the selected range (horizontal), and, therefore, only

the single lamp corresponding to both the selected range and scale will go on since it is the only one which receives both the ground and positive potentials.

Transistor Q14 is normally biased "off" when a Series 422, 421 or 420 tft Power Head is connected due to the clamping action of two grounded diodes CR13, CR14, and/or CR15. When a Model N423, which has no grounded interlock pins, is connected to the Model 460, transistor Q14 will be biased "on" since none of the diodes is grounded. This establishes the activating ground potential at the collector of Q14, and, therefore, on indicator lamps DS26-DS32. This also establishes a negative potential at the base and emitter of Q15, which, in turn, clamps the bases of Q11, Q12 and Q13 at a negative potential, thereby biasing them "off". This removes the activating ground potential from the other three scales and ensures that only the scale corresponding to the Model N423 remains activated. (Note that if no tft power head is connected to the Model 460, none of the interlock pins is grounded, and the display is identical to that of the Model N423.)

3.2.6 MODULATOR/DEMODULATOR DRIVER.

This circuit is an astable multivibrator. The values of resistors R66 and R67, and capacitors C39 and C42 establish operation at 83 Hz. The output of the multivibrator is applied directly to the chopper energizing coil.

3.2.7 MODEL N423 NON-LINEARITY COMPENSATION NETWORK (MODEL 460B ONLY)

This network consists of diode CR5, relay K1 and resistor R45. When a Model N423 is connected to the Model 460B and the 3W RANGE button is depressed, relay K1 is energized, and the compensation network reduces the gain of amplifier AR1. The circuit parameters are such that compensation for the non-linearity of the Model N423 results, and the correction factor reduction described in the Model N423 literature need not be applied.

SECTION IV - MAINTENANCE

4.1 GENERAL PARTS INFORMATION

Standard readily available components are used in the manufacture of GMC instruments whenever possible. Such parts can usually be obtained from a local dealer. Special or modified parts, as determined by an entry in the last column of the Table of Replaceable Parts, are available from GMC.

When ordering parts from GMC, please indicate your instrument model and serial number, plus the data given in the Table of Replaceable Parts.

4.2 INSTRUMENT REMOVAL

To gain access to the interior of a Model 460, remove the ac line cord and the two screws at the rear of the unit, the two screws at the bottom of the unit, and carefully withdraw the panel-chassis assembly from the cabinet.

To gain access to the interior of a rack-mounted Model 460, first remove the rack adapter from the rack, and then remove the Model 460 from the rack adapter by removing the four screws which secure the Model 460 to the rack adapter. Then proceed as described above.

4.3 EQUIPMENT REQUIRED FOR TEST AND CALIBRATION

Use the test equipment listed in table 4.1 or equivalents in the performance of the test and calibration procedures.

4.4 SPECIAL MAINTENANCE PRECAUTIONS

4.4.1 Do not make resistance checks on input transformer T1.

4.4.2 All circuits use either transistors or integrated circuits. Do not make resistance checks using the lower ohmmeter ranges.

4.4.3 Because of the very low dc voltages involved, repair of the Model 460 must be conducted with special care. All connections to the input circuit must be made only with unplated copper leads, and all solder connections must be made with low-thermal solder using a soldering iron with an unplated copper tip which has been employed only with that type of solder, a length of which is furnished with each Model 460.

4.4.4 If replacement of connector J3 becomes necessary, refer to note 4 on figure 3.2.

4.5 WARM-UP

4.5.1 Before applying ac power, depress the POWER LINE OFF button, and make continuity checks to ensure that neither side of the line cord is connected to the chassis.

4.5.2 Mechanically zero the meter, if necessary, and connect the variable autotransformer to a source of 115 volt, 50-1000 Hz power.

TABLE 4.1 REQUIRED TEST EQUIPMENT

DESCRIPTION	MFR.	MODEL
Calibrator	GMC	305B
Oscilloscope	Tektronix	503
Dc Voltmeter	Fluke	825A
Electronic Counter	H-P	524D
Multimeter	Simpson	260
Variable Autotransformer	Superior Electric	116
Ac Voltmeter	GE	A0-91

4.5.3 Set the Model 460 115V-230V LINE switch to 115V and the RESPONSE switch to NORM. Connect the Model 460 to the variable autotransformer and set the line voltage to 115 volts using the ac voltmeter.

4.5.4 Connect the calibrator to either INPUT connector. Depress its ZERO and ON/OFF buttons.

4.5.5 Depress the POWER LINE ON button. The associated indicator lamp should go on. Allow a five-minute warm-up period before proceeding.

4.6 SENSITIVITY SELECTION LOGIC TEST

4.6.1 Depress the calibrator 10 mW button.

4.6.2 Depress the 10 mW RANGE button on the unit under test and verify that the appropriate indicator lamp goes on.

4.6.3 Rotate the SCALE ILLUM control from the fully counterclockwise setting to the fully clockwise setting and verify that the indicator lamp intensity varies. Adjust it for a convenient lamp intensity.

4.6.4 Sequentially depress the 3 mW through 3 uW RANGE buttons on the unit under test and verify that the appropriate indicator lamps go on.

4.6.5 Check that the 3 uW RANGE button is depressed. Depress the calibrator 1 mW, 100 mW and 3 W buttons, verify that the .3 uW, 30 uW and 3 mW indicator lamps on the unit under test, respectively, go on, and depress the calibrator 10 mW button.

4.7 POWER SUPPLY TESTS

4.7.1 +8 VOLT POWER SUPPLY REGULATION TESTS.

4.7.1.1 Adjust the line voltage to 103 volts.

4.7.1.2 Using the dc voltmeter, verify that the voltage between TP4 (+) and ground is between 7.5 and 8.4 volts.

4.7.1.3 Adjust the line voltage to 127 volts, and verify that the dc voltmeter indicates between 7.5 and 8.4 volts.

4.7.1.4 If the unit under test has a charged Model 981 Battery Pack installed, depress the BAT ON button and verify that the dc voltmeter indicates between 7.5 and 8.4 volts. Depress the POWER LINE ON button.

4.7.2 -8 VOLT POWER SUPPLY REGULATION TESTS.

4.7.2.1 Connect the dc voltmeter between TP3 (-) and ground, and verify that it indicates between -7.5 and -8.4 volts.

4.7.2.2 Adjust the line voltage to 103 volts, and verify that the dc voltmeter indicates between -7.5 and -8.4 volts.

4.7.2.3 If the unit under test has a charged Model 981 Battery Pack installed, repeat step 4.7.1.4.

4.7.3 POWER SUPPLY RIPPLE TESTS.

4.7.3.1 Using the oscilloscope, verify that the peak-to-peak ripple between TP4 and ground does not exceed 1 mV.

4.7.3.2 Repeat step 4.7.3.1 at TP3.

4.8 CARRIER FREQUENCY TESTS AND ADJUSTMENTS

4.8.1 CHOPPER DRIVE FREQUENCY TESTS.

4.8.1.1 Adjust the line voltage to 115 volts.

4.8.1.2 Connect the electronic counter between TP2 and ground, and adjust potentiometer R35 for an indication on the electronic counter of 83 ±0.5 Hz. Remove the electronic counter.

4.8.2 FILTER ADJUSTMENT.

4.8.2.1 Depress the POWER LINE OFF button and remove integrated circuit AR4 from its socket.

4.8.2.2 Connect the oscilloscope between TP1 and ground, and depress the 10 mW RANGE button on the unit under test.

4.8.2.3 Depress the POWER LINE ON button and adjust potentiometer R39 for a symmetrical, negative-going, full wave rectified sine wave with a notch centered between the negative-going pulses. Depress the POWER LINE OFF button and replace AR4. Depress the POWER LINE ON button.

4.9 DC ZERO ADJUSTMENT

4.9.1 Connect the dc voltmeter to the OUTPUT connector.

4.9.2 Rotate the OUTPUT ADJUST control fully clockwise to its detented position.

4.9.3 Adjust potentiometer R1 for a 0±0.3 mV indication on the dc voltmeter.

4.9.4 Depress the 10 uW RANGE button on the unit under test and adjust the METER ZERO control for a 0±5.0 mV indication on the dc voltmeter.

4.9.5 Continue to repeat steps 4.9.3 and 4.9.4 until no additional adjustments are required.

4.10 RANGE-TO-RANGE ACCURACY TESTS

4.10.1 Release the calibrator ZERO button, set its POWER RANGE buttons in accordance with the second column of the tabulation given below and verify that the indications on the dc voltmeter connected to the OUTPUT connector are within the limits indicated in the third column of the tabulation. At each range setting, re-check the Model 460 zero.

Depressed Model 460 RANGE Button	Model 305B POWER RANGE Button	OUTPUT Dc Vtvm Limits (V)	
		From	To
10 mW	8	0.995	1.005
3 mW	7	0.3144	0.3176
1 mW	6	0.995	1.005
0.3 mW	5	0.3144	0.3176
0.1 mW	4	0.995	1.005
30 uW	3	0.3144	0.3176
10 uW	2	0.995	1.005
3 uW	1	0.3144	0.3176

NOTE

Step 4.10.2 is applicable only to Models 460B. Delete it when testing Models 460.

4.10.2 Depress the calibrator POWER RANGE 7 and 3 W buttons and the 3 W button on the unit under test, verify that the indication on the dc voltmeter connected to the OUTPUT connector is between 0.297 and 0.303 volt, and depress the 10 mW button on the calibrator.

4.11 METER SENSITIVITY CALIBRATION

4.11.1 Depress the 10 mW RANGE button on the unit under test.

4.11.2 Depress the calibrator POWER RANGE 8 button.

4.11.3 Adjust potentiometer R21 for an indication of 10 on the 10 scale of the Model 460 meter.

4.11.4 Depress the 3 mW RANGE button on the unit under test.

4.11.5 Depress the calibrator POWER RANGE 7 button.

4.11.6 Adjust potentiometer R19 for an indication of 10 on the 10 scale of the Model 460 meter.

4.12 NOISE TEST

4.12.1 Depress the 3 uW RANGE button on the unit under test. Depress the calibrator ZERO button.

4.12.2 Adjust the METER ZERO control for an indication of 5 on the 10 scale of the Model 460 meter. Verify that the noise as seen on the meter is less than 1% of full scale (1/2 of one small division peak-to-peak).

4.13 ZERO CARRYOVER TEST

4.13.1 Adjust the METER ZERO control for an indication of 0 on the Model 460 meter.

4.13.2 Sequentially depress each of the remaining RANGE buttons and verify that the Model 460 meter indicates 0 at all positions.

4.14 RESPONSE TIME TEST

4.14.1 Connect the oscilloscope to the OUTPUT connector.

4.14.2 Depress the 3 uW RANGE button on the unit under test.

4.14.3 Release the calibrator ZERO button and depress its POWER RANGE 1 button.

4.14.4 Set the oscilloscope sensitivity and sweep rate to 0.1 V/CM and 0.5 SEC/CM, respectively.

4.14.5 Depress the calibrator ZERO button.

4.14.6 Adjust the METER ZERO control for a 0 indication on the Model 460 meter.

4.14.7 While observing the oscilloscope, verify that the rise time (10% to 90%) of the waveform is between 0.5 and 1.5 seconds after the ZERO button is released.

4.14.8 Set the RESPONSE switch to FAST and repeat steps 4.14.5 and 4.14.6.

4.14.9 Set the oscilloscope sweep rate to 0.1 CM/SEC and repeat step 4.14.7. The rise time

should be between 50 and 150 milliseconds. Set the RESPONSE switch to NORM.

4.15 OUTPUT ADJUST TEST

4.15.1 Depress the 10 mW RANGE button on the unit under test.

4.15.2 Release the calibrator ZERO button and depress its POWER RANGE 8 button.

4.15.3 Rotate the OUTPUT control counterclockwise and verify that the indication on the oscilloscope varies from -1 volt to 0. Rotate the OUTPUT control fully clockwise to its detented position.

TABLE OF REPLACEABLE PARTS

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
AR1-4	Amplifier, IC; P/N U5B770939X	4	07263	
BT1, 2	Battery, rechargeable (optional)	2	11332	5239A-3
CR1-4	Semiconductor device, diode; Type 1N914	7	81349	
CR5**	Semiconductor device, diode; P/N 5082-2900	1	28480	
CR6-12	Semiconductor device, diode; Type 1N2070	7	81349	
CR13-15	Same as CR1			
CR16-46	Semiconductor device, diode; Type 1N281	32	81349	
CR47**	Semiconductor device, diode; Type 1N914	1	82647***	
CR48	Same as CR16			
C1	Not Used			
C2	Capacitor, fixed, ceramic, .005 μF; P/N TG-D50	3	56289	
C3	Capacitor, fixed, ceramic, 200 pF; P/N DD-201	2	71590	

** Used only in the Model 460B.
*** TI only; no equivalents.

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
C4	Capacitor, fixed, ceramic, .01 μF; P/N TG-S10	8	56289	
C5	Not Used			
C6	Same as C4			
C7	Capacitor, fixed, tantalum, 68 μF; P/N K68E10	1	05397	
C8	Capacitor, fixed, ceramic, 0.1 μF; P/N HY-360	3	56289	
C9	Capacitor, fixed, tantalum, 150 μF; P/N K150E6	1	05397	
C10	Not Used			
C11	Capacitor, fixed, tantalum, 22 μF; P/N K22E10	2	05397	
C12	Capacitor, fixed, tantalum, 47 μF; P/N K47E6	1	05397	
C13	Same as C4			
C14	Capacitor, fixed, ceramic, .05 μF; P/N TG-S50	2	56289	
C15	Not Used			
C16	Same as C2			
C17	Same as C4			
C18	Same as C4			
C19	Capacitor, fixed, mylar, 0.1 μF; P/N DMF1P1-10	2	14655	
C20	Not Used			
C21	Same as C19			
C22	Capacitor, fixed, ceramic, 500 pF; P/N CE-501	1	71590	
C23	Capacitor, fixed, ceramic, 20 pF; P/N DD-200	1	71590	
C24	Same as C4			
C25	Not Used			
C26	Same as C11			
C27	Not Used			
C28	Capacitor, fixed, polyester, 0.68 μF ±10%; P/N C281CH/A680K	2	73445	
C29	Same as C28			
C30	Not Used			
C31	Same as C14			
C32	Capacitor, fixed, tantalum, 1 μF ±10%; P/N 150D105X9035A2	1	56289	

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
C33 (Model 460)	Capacitor, fixed, tantalum, 15 μF ±10%; P/N 150D156X9035R2	1	56289	
C33 (Model 460B)	Capacitor, fixed, tantalum, 39 μF ±10%; P/N 150D396X9020R2	1	56289	
C34	Same as C4			
C35	Not Used			
C36	Same as C3			
C37	Same as C2			
C38	Same as C4			
C39	Capacitor, fixed, tantalum, 4.7 μF; P/N K4R7C35K	2	05397	
C40	Not Used			
C41	Not Used			
C42	Same as C39			
C43	Capacitor, fixed, electrolytic, 500 μF; P/N TL-1217	1	56289	
C44	Capacitor, fixed, electrolytic, 1000 μF; P/N TVL-1230	2	56289	
C45	Not Used			
C46	Same as C44			
C47	Capacitor, fixed, ceramic, 47 pF, ±5%; P/N 851-000C0G0470J	2	71982	
C48	Same as C47			
C49	Capacitor, fixed, tantalum, 4.7 μF; P/N K4R7W15	2	05397	
C50	Same as C8			
C51	Same as C49			
C52	Same as C8			
C53	Capacitor, fixed, tantalum, 33 μF; P/N 196D336X0015FB	1	56289	
DS1	Lamp, neon; P/N PLN-100	1	95146	
DS2-33	Lamp, incandescent; P/N CM7-2162	32	71744	
F1	Fuse, 1/10 A, SLO-BLO; P/N 313.100	1	75915	
G1	Chopper, electronic	1	11332	3153G-5
J1,2	Connector, receptacle, electrical	2	11332	2907B
J3	Connector, receptacle, electrical; P/N 1061-5	1	87930	
J4	Binding post assembly; P/N's 29-1 BLK, 29-1 RED and 29B11-1	1	81073	
K1*	Relay; P/N RA30191121	1	15636	
M1	Meter	1	11332	4987D-3
Q1-3	Transistor, Type 2N5138	7	04713	

* Used only in the Model 460B.

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
Q4	Transistor; Type 2N5133	1	04713	
Q5-8	Same as Q1			
Q9,10	Transistor; P/N 40391	2	02735	
	OR			
	Transistor; Type 2N4036 with Heatsink; P/N NF205	2 2	81349 05820	
Q11-15	Transistor; Type 2N5135	5	04713	
R1	Resistor, variable, film, 25K ohms ±20%; P/N 360T253B	1	71450	
R2	Resistor, fixed, film, 475K ohms ±1%; Style RN60C	1	81349	
R3	Resistor, fixed, film, 681 ohms ±1%; Style RN60C	1	81349	
R4	Resistor, fixed, wire-wound, 2000 ohms ±0.05%; Style RB56E	1	81349	
R5	Resistor, fixed, wire-wound, 1000 ohms ±0.05%, Style RB56E	1	81349	
R6	Resistor, fixed, composition, 1500 ohms ±5%; Style RC07	6	81349	
R7	Resistor, fixed, composition, 51 ohms ±5%; Style RC07	4	81349	
R8	Resistor, fixed, film, 100K ohms ±1%; Style RN60C	3	81349	
R9	Same as R8			
R10	Resistor, fixed, film, 301 ohms ±1%; Style RN60C	1	81349	
R11	Resistor, fixed, film, 2317 ohms ±0.1%; Style RN60C	1	81349	
R12	Resistor, fixed, composition, 100K ohms ±5%; Style RC07	6	81349	
R13	Resistor, fixed, film, 20.94K ohms ±0.1%; Style RN60C	1	81349	
R14	Resistor, fixed, composition, 10K ohms ±5%; Style RC07	2	81349	
R15	Resistor, fixed, film, 209.4K ohms ±0.1%; Style RN60C	1	81349	
R16	Resistor, fixed, composition, 1000 ohms ±5%; Style RC07	1	81349	
R17	Resistor, fixed, film, 2.094 megohms ±0.1%; P/N 9852-2B	1	65092	
R18	Resistor, fixed, composition, 100 ohms ±5%; Style RC07	2	81349	
R19	Resistor, variable, film, 50 ohms ±20%; P/N 360T500B	1	71450	

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
R20	Resistor, fixed, film, 287 ohms ±1%; Style RN60C	1	81349	
R21	Resistor, variable, film, 200 ohms ±20%; P/N 360T201B	1	71450	
R22	Resistor, fixed, film, 909 ohms ±1%; Style RN60C	1	81349	
R23	Resistor, variable, wire-wound, 25K ohms	1	11332	3982C-3
R24	Resistor, fixed, wire-wound, 111.07 ohms ±0.05%; Style RB56E	1	81349	
R25	Resistor, variable, composition, 1000 ohms	1	11332	5243B-3
R26	Resistor, fixed, wire-wound, 10 ohms	1	11332	2643E
R27	Resistor, fixed, composition, 16K ohms ±5%, Style RC07	1	81349	
R28	Same as R8			
R29	Resistor, fixed, film, 249K ohms ±1%; Style RN60C	1	81349	
R30 (Model 460)	Resistor, variable, composition, 250 ohms	1	11332	5242C-3
R30 (Model 460B)	Resistor, variable, composition, 100 ohms	1	11332	5242C-5
R31, R32	Same as R12			
R33	Same as R6			
R34	Resistor, fixed, composition, 220K ohms ±5%; Style RC07	1	81349	
R35*	Resistor, variable, film, 500 ohms ±20%; P/N 360T501B	2	71450	
R36	Same as R7			
R37	Resistor, fixed, composition, 470K ohms ±5%; Style RC07	1	81349	
R38	Resistor, fixed, film, 3160 ohms ±1%; Style RN60C	1	81349	
R39	Same as R35			
R40	Resistor, fixed, film, 576 ohms ±1%; Style RN60C	1	81349	
R41	Same as R12			
R42	Resistor, fixed, film, 634K ohms ±1%; Style RN60C	1	81349	
R43	Same as R6			
R44	Same as R7			
R45*	Resistor, fixed, film, 15.4K ohms ±1%; Style RN60C	1	81349	
R46	Resistor, fixed, composition, 68K ohms ±5%; Style RC07	1	81349	
R47	Resistor, fixed, composition, 24K ohms ±5%; Style RC07	1	81349	

* Used only in the Model 460B.

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
R48	Resistor, fixed, composition, 4700 ohms ±5%; Style RC07	4	81349	
R49	Same as R48			
R50	Resistor, fixed, composition, 47K ohms ±5%; Style RC07	3	81349	
R51	Resistor, fixed, composition, 3300 ohms ±5%; Style RC07	1	81349	
R52	Resistor, fixed, composition, 3900 ohms ±5%; Style RC07	6	81349	
R53	Same as R50			
R54	Same as R12			
R55	Same as R14			
R56	Same as R50			
R57	Resistor, fixed, composition, 4.7 megohms ±5%; Style RC07	1	81349	
R58 (Model 460)	Resistor, fixed, composition, 110K ohms ±5%; Style RC07	1	81349	
R58 (Model 460B)	Resistor, fixed, composition; Style RC07; Select value at test	1	81349	
R59	Same as R6			
R60*	Resistor, fixed, composition, 150 ohms ±5%; Style RC07	1	81349	
R61	Resistor, fixed, composition, 8200 ohms ±5%; Style RC07	1	81349	
R62	Same as R7			
R63	Resistor, fixed, composition, 200 ohms ±5%; Style RC07	1	81349	
R64	Same as R18			
R65	Same as R48			
R66	Resistor, fixed, film, 1580 ohms ±1%; Style RN60C	2	81349	
R67	Same as R66			
R68	Same as R48			
R69*	Resistor, fixed, composition, 300 ohms ±5%; Style RC05	1	81349	
R70	Not Used			
R71	Resistor, fixed, composition, 20 ohms ±5%; Style RC07	1	81349	
R72	Resistor, fixed, composition, 1 ohm ±10%; P/N EB10G1	2	01121	
R73	Same as R72			
R74	Resistor, fixed, film, 9090 ohms ±1%; Style RN60C	2	81349	
R75	Not Used			

* Used only in the Model 460B.

TABLE OF REPLACEABLE PARTS (Cont)

REF DES	DESCRIPTION	TOTAL NO. USED	MFRS CODE	GMC DWG NO.
R76	Resistor, fixed, film, 2490 ohms ±1%; Style RN60C	2	81349	
R77	Same as R74			
R78	Same as R76			
R79	Resistor, fixed, composition, 36K ohms ±5%; Style RC07	1	81349	
R80	Same as R6			
R81	Resistor, fixed, composition, 51 ohms ±5%; Style RC42	2	81349	
R82	Same as R6			
R83	Same as R81			
R84	Same as R12			
R85	Resistor, fixed, composition, 20 ohms ±5%; Style RC32	1	81349	
R86	Resistor, fixed, composition, 2000 ohms ±5%; Style RC07	4	81349	
R87	Same as R52			
R88	Same as R86			
R89	Same as R52			
R90	Same as R86			
R91	Same as R52			
R92	Same as R52			
R93	Same as R86			
R94	Same as R52			
R95	Resistor, fixed, composition, 6200 ohms ±5%; Style RC07	1	81349	
R96	Resistor, fixed, composition, 750 ohms ±5%; Style RC07	1	81349	
S1	Switch, pushbutton, 8 station	1	11332	5058C-3
S2	Switch, SPDT; P/N GF-324	1	79727	
S3	Switch, DPDT; P/N GF-326 modified w/.031 slotted knob	1	79727	
S4	Switch, pushbutton, 5 station	1	11332	5057C-3
S5	Switch; part of R25			
T1	Transformer, af	1	11332	5047B-3
T2	Transformer, power, step-down	1	11332	4995C-3
TP1-4	Test point; P/N 8436401-166G4	4	49956	
W1	Ac cord set, 3 conductor; P/N 17258	1	70903	
VR1,2	Voltage regulator, IC; P/N LM305A	2	12040	

LIST OF MANUFACTURERS' CODES

CODE	MANUFACTURER	ADDRESS
01121	Allen Bradley Co.	Milwaukee, Wisc.
02735	Radio Corp. of America	Harrison, N.J.
04713	Motorola Semiconductor Products, Inc.	Phoenix, Arizona
05397	KEMET Div. of Union Carbide Corp.	Cleveland, Ohio
05820	Wakefield Engineering, Inc.	Wakefield, Mass.
07263	Fairchild Semiconductor Products, Inc.	Phoenix, Arizona
11332	General Microwave Corporation	Farmingdale, N.Y.
12040	National Semiconductor Corp.	Santa Clara, Calif.
14655	Cornell-Dubilier Electronics	Newark, N.J.
15636	Elec-trol Inc.	Saugus, Calif.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
49956	Raytheon Co.	Quincy, Mass.
56289	Sprague Electric Co.	N. Adams, Mass.
65092	Weston Instruments, Inc.	Newark, N.J.
70903	Belden Corp.	Chicago, Ill.
71450	CTS of Berne, Inc.	Berne, Ind.
71590	Centralab Electronics Div.	Milwaukee, Wisc.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71982	Erie Technological Prods., Inc.	Erie, Pa.
73445	Amperex Electronic Corp.	Hicksville, N.Y.
75915	Littelfuse, Inc.	W. Hartford, Conn.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
81073	Grayhill, Inc.	La Grange, Ill.
81349	Government Specifications	Any Manufacturer
82647	Texas Instruments, Inc.	Dallas, Texas
87930	Tower Mfg. Corp.	Providence, R.I.
95146	Alco Electronic Products	Lawrence, Mass.

EQUIPMENT WARRANTY

General Microwave Corporation warranties all parts of equipment of its manufacture to be free from defects caused by faulty material or poor workmanship. This warranty excludes electronic tubes, batteries, natural rubber and material normally consumed in operation unless such excepted items fail as a result of improper application by General Microwave.

Liability under this warranty is limited to the obligation to repair, or, at General Microwave's sole option, to replace without charge, FOB General Microwave's Plant, any part found to be defective under normal use and service within the time periods shown below, provided:

(1) General Microwave Corporation is promptly notified within the warranty period in writing upon discovery of such defects;

(2) The original parts or equipment are returned to General Microwave Corporation, transportation charges prepaid;

(3) General Microwave Corporation's examination shall disclose to its satisfaction that such defects have not been caused by abuse after delivery; and

(4) Warranties shall not apply to items which have been repaired or altered by others than General Microwave Corporation or its authorized agency.

The period of warranty is one year after delivery of the instrument to the original purchaser.

The warranty period shall not include any period of time the unit or part fails to perform satisfactorily due to such defect, and any unit, part or component repaired or replaced by General Microwave pursuant to this warranty shall itself be guaranteed as specified above.